Original Article

Thulium Fiber Laser Versus Holmium:Yttrium Aluminium Garnet (Ho:YAG) in Flexible Ureteroscopy: A Comparative Study of Stone Dusting Outcomes

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ABSTRACT

Objective: To compare the efficacy and safety of thulium fiber laser and Holmium:Yttrium Aluminium Garnet lasers during flexible ureteroscopy for renal calculi.

Study Design: Prospective comparative research study.

Place and Duration of Study: This study was conducted at the Department of Urology, Al-Kafeel Hospital, Iraq from 15th August 2024 to 31st July 2025.

Methods: A research including 193 cases with renal stone of 10-20 mm. The patients were divided into groups; group A (thulium fiber laser dusting group) included 95 patients and group B (Holmium:Yttrium Aluminium Garnet l dusting) included 98 patients. The volumetric evaluation and maximal diameter of the stone were determined by non-contrast computed tomography. The operative time and stone free rate for four weeks after the operation were the primary outcomes. Secondary outcomes were perioperative complications, which were categorized according to the Clavien-Dindo classification.

Results: In Holmium:Yttrium Aluminium Garnet group, the thulium fiber laser had a considerably lower mean operating time (55±7 vs. 64±9 minutes; mean difference 9 minutes, 95% CI 7–11; $p < 0.001$). At four weeks, the thulium fiber laser had a higher stone free rate (92%) than the Holmium:Yttrium Aluminium Garnet group (87%), although the difference was not statistically significant (absolute difference 5%, 95% CI –3 to 12; $p = 0.22$). Only modest Clavien-Dindo grade I–II events and complication rates were similar between groups. **Conclusion:** During flexible ureteroscopy, thulium fiber laser outperforms Holmium:Yttrium Aluminium Garnet in terms of operational efficiency, safety, and a trend toward greater stone-free rates. These results call for additional validation in multicenter randomized trials and support the broader therapeutic usage of thulium fiber laser.

Key Words: Thulium fiber laser, Yttrium Aluminium Garnet, Stone free rate, Flexible ureteroscopy

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INTRODUCTION

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Urolithiasis constitutes a significant and growing global health burden, with increasing prevalence and substantial implications for healthcare utilization. Advances in endourological techniques have positioned flexible ureteroscopy (fURS) as a first-line treatment for renal and proximal ureteral stones, offering high efficacy with minimal invasiveness.[1] Within this context, laser lithotripsy technology plays a pivotal role in determining procedural success, particularly when a dusting strategy is employed to facilitate spontaneous fragment clearance. For decades, the Holmium:YAG (Ho:YAG) laser has been regarded as the reference standard for intracorporeal lithotripsy due to its broad applicability across stone compositions and established safety profile.[2] However, technical limitations-including higher pulse energy requirements, increased stone retropulsion, and comparatively less efficient fine dust generation-may restrict its performance during flexible ureteroscopy, where efficient fragmentation without basket extraction is essential.[3]

The thulium fiber laser (TFL) has recently emerged as a novel alternative, characterized by a wavelength (1940 nm) that closely aligns with the absorption peak of water.[4] This property allows more efficient energy delivery, lower ablation thresholds, and the production of finer stone particles with minimal retropulsion. Furthermore, TFL enables operation at ultra-low pulse energies and very high frequencies, features that are particularly advantageous for stone dusting and may translate into improved operative efficiency and clinical outcomes.[5] Despite growing clinical adoption, robust comparative evidence assessing TFL against the conventional Ho:YAG laser in flexible ureteroscopy remains limited. In particular, stone dusting outcomes an increasingly favored lithotripsy strategy-have not been sufficiently evaluated in well-designed comparative studies. This gap in evidence limits the ability to draw definitive conclusions regarding the optimal laser platform for contemporary endourological practice.[6]

Renal calculi smaller than 20 mm can be effectively treated by fURS. The gold standard for ureteroscopic lithotripsy is still Ho:YAG. With its higher frequency, lower pulse energy, and smaller fiber diameters, the TFL, which was recently introduced, may maximize stone dusting.[7] According to preclinical research, TFL outperforms Ho:YAG in terms of faster ablation, decreased retropulsion, and finer dust.[8] With an emphasis on operational time, SFR, and safety, this study compared TFL and Ho:YAG dusting during fURS using standardized CT volumetry for stone assessment. Nephrolithiasis has risen markedly on a global scale over the past two decades.[9] By 2011, the morbidity rate associated with nephrolithiasis ranged from 1.2–1.4% in Europe and 1–5% in China.[10] The origins, diagnostic approaches, and treatment modalities for nephrolithiasis have all undergone substantial advancement. Extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCNL), and flexible ureteroscopy (FURS) are currently employed in its management. For stones up to 20 mm, ESWL produces favorable stone-free rates (SFR); however, the SFR attained with ESWL is obviously influenced by the size, location, and composition of the stone. When there are several kidney stones, its efficacy decreases by around 50%.[11]

According to the 2013 European Association of Urology (EAU) guidelines[12], percutaneous nephrolithotomy (PCNL) is still the recommended first-line treatment for patients with renal stones larger than 20 mm or multiple renal calculi; however, its use is restricted to those who are morbidly obese, have a coagulopathy, or are pregnant. Since Marshall's 1964 demonstration of a ureterostomy (FURS) from diagnostic to therapeutic purposes.[13] Despite the fact that the FURS approach is not recommended by the EAU recommendations on urolithiasis as the conventional initial therapy for renal stones larger than 15 mm, a number of studies have presented data on the procedure and have recommended its usage due to its high success rates and low complication rates.[12] Accordingly, the primary aim of this study is to compare the stone dusting efficiency of thulium fiber laser and Ho:YAG laser during flexible ureteroscopy. Secondary objectives include assessment of operative time, laser energy utilization, stone-free rates, retropulsion, and perioperative safety. We hypothesize that Thulium Fiber Laser–assisted flexible ureteroscopy provides superior stone dusting efficiency and procedural performance compared to Ho:YAG laser, without compromising patient safety.

METHODS

This prospective, single-center observational study was conducted at Al-Kafeel Hospital's Iraq from at Department of Urology, Al-Kafeel Hospital, Iraq from 15th August 2024 to 31st July 2025 vide letter No. 4545/QM/Approval/9389JFDNF dated 11th August, 2024. A total of 193 cases with renal stone of 10-20 mm were included. Every patient gave their informed consent, and ethical approval was secured. Adults ≥18 years old, renal stones 10–20 mm on NCCT, no history of PCNL, and normal renal architecture are the requirements for inclusion. Anatomical anomalies, strictures, coagulopathy, and pregnancy are the exclusion criteria. The patients were divided into groups; group A (thulium fiber laser dusting group) included 95 patients and group B (Ho:YAG l dusting) included 98 patients. The same surgical team used flexible ureteroscopes (7.5 Fr) with 200 µm fibers to perform all procedures under general anesthesia.

Ho:YAG 0.6–0.8 J, 10–20 Hz; TFL 0.15–0.2 J, 1500–2000 Hz. After surgery, DJ stents were given to every patient. Stone assessment: Blinded radiologists measured the ellipsoid volumetry ($\pi/6 \times L \times W \times D$), maximal diameter, and NCCT with a slice thickness of ≤3 mm. NCCT at four weeks is the follow-up. SFR is defined as having no fragments larger than 2 mm. Clavien-Dindo graded complications. Statistics: t-test is used to evaluate continuous data, whereas χ^2 is used to study categorical data. 95% CI and effect sizes were provided. The sample size needed to detect a ≥10% SFR difference at α=0.05 was validated by power analysis.

RESULTS

The stone size and demography of the groups were similar. Figures 1 and 2 showed the not significant differences between age and stone size, respectively in all patients. Table 1 provides a summary of detailed baseline characteristics. TFL had shorter mean operative time (55±7 min) compared to Ho: YAG (64±9 min, $p<0.001$).

Table No. 1: Comparison of baseline characteristics

Variable	TFL (n=95)	Ho:YAG (n=98)	p-value
Age (years)	47.0±12.1	46.5±11.8	0.76
Male (%)	62%	64%	0.81
Stone size (mm)	16.9±1.2	16.7±1.3	0.33

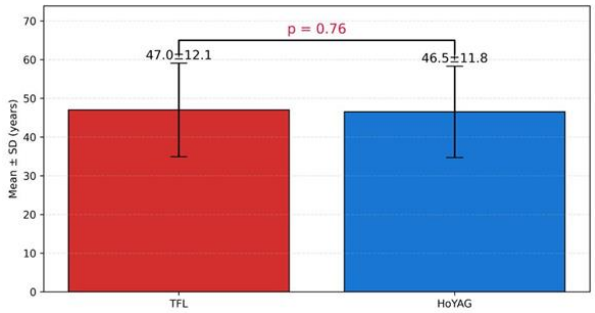

Figure No. 1: Comparison of age between TFL and Ho:YAG groups

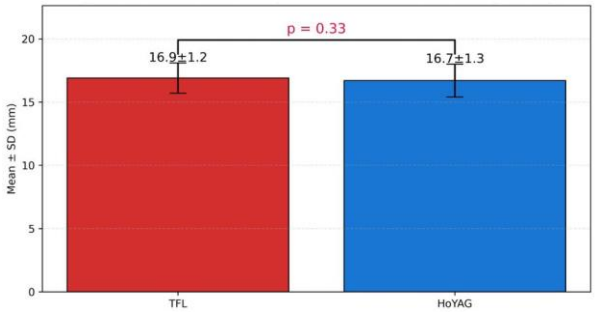

Figure No. 2: Comparison of stone size between TFL and Ho:YAG groups

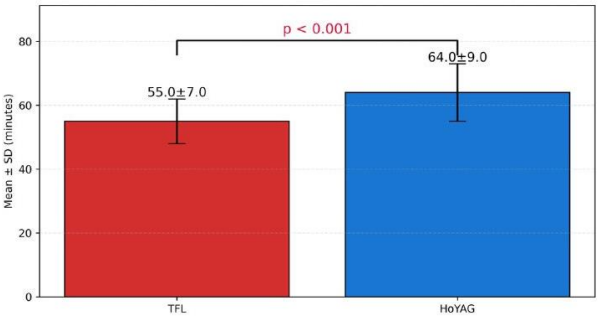

Figure No. 3: Comparison of operative time between TFL and Ho:YAG groups

Table No. 2: Comparison of operative outcomes

Variable	TFL (n=95)	Ho:YAG (n=98)	p-value
Operative time (min)	55±7	64±9	<0.001
SFR at 4 weeks	92%	87%	0.22
Complications (major)	-	-	-

Operative time differences are depicted in Figure 3, demonstrating a significant (<0.001) advantage for TFL (Table 2). At 4 weeks, SFR was 92% in the TFL group vs 87% in the Ho: YAG group (p=0.22). The comparative SFR outcome was showing modest and non-significant advantage for TFL (Fig. 4).

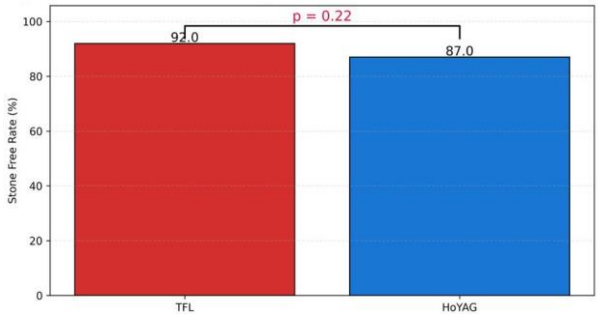

Figure No. 4: Comparison of stone free rate between TFL and Ho:YAG at 4 weeks

DISCUSSION

In the present study, thulium fiber laser achieves shorter operative times and slightly higher SFR compared to Ho:YAG in fURS dusting for 10-20 mm renal stones. These results are consistent with Xu et al[14] and with preclinical data showing superior ablation efficiency and reduced retropulsion with TFL. Although the SFR difference (5%) was not statistically significant, the trend favors TFL as compared with other studies.[15,16] The significant reduction in operative time is clinically important for improving workflow efficiency and patient outcomes. Complication profiles were similar, confirming both lasers as safe options for clinical use.[17,18] The non-significant SFR difference (Fig. 4) and significant time advantage (Fig. 3) reinforce TFL's procedural efficiency.[19] Baseline comparability ensures unbiased comparison. Strengths include prospective design, standardized CT volumetry, and homogeneous groups (Figs. 1-2, Table 1). Specifically, TFL was associated with a statistically significant reduction in operative time and a non-significant but clinically relevant improvement in SFR at four weeks.

This study showed that observed reduction in operative time with TFL is consistent with its distinct physical and technical properties. The higher water absorption coefficient of TFL at a wavelength of 1940 nm allows more efficient energy transfer to the stone fluid interface, resulting in faster ablation rates and finer dust production at lower pulse energies. This mechanism has been repeatedly demonstrated in preclinical and in vitro studies, which reported superior ablation efficiency and markedly reduced retropulsion compared with Ho:YAG lasers.[20] Our clinical findings corroborate these experimental observations and align with prior prospective and multicenter studies reporting shorter operative times when TFL is employed for dusting strategies.

In the present study, the difference in SFR between the two groups did not reach statistical significance, the

higher SFR observed in the TFL group (92% vs. 87%) suggests a favorable trend toward improved stone clearance. This finding may be attributed to the generation of finer dust particles with TFL, which facilitates spontaneous evacuation and reduces dependence on basket extraction.[21,22] From a clinical perspective, even modest improvements in SFR may translate into fewer ancillary procedures, reduced patient morbidity, and lower healthcare costs, particularly in high-volume endourology centers.

Importantly, both laser modalities demonstrated comparable safety profiles, with only minor Clavien Dindo grade III complications observed and no major adverse events in either group. This confirms that the enhanced efficiency of TFL does not come at the expense of increased perioperative risk. Reduced retropulsion associated with TFL may further contribute to procedural safety by minimizing unintended stone migration and decreasing the need for prolonged manipulation within the collecting system.

The use of standardized non-contrast CT volumetry and uniform follow-up protocols strengthens the validity of our findings. Accurate stone measurement and consistent SFR definitions are essential for meaningful comparison between laser technologies, as emphasized in contemporary endourological reporting standards. Baseline equivalence between groups in terms of stone size, patient demographics, and operative technique further supports the reliability of the comparative outcomes observed.

Despite these strengths, certain limitations warrant consideration. The single-center design may limit the generalizability of the results, and laser allocation based on availability rather than randomization introduces the potential for selection bias. Additionally, the follow-up period was limited to four weeks; longer follow-up may be necessary to assess late fragment passage and recurrence rates. Future multicenter randomized controlled trials with extended follow-up and cost-effectiveness analyses are therefore required to fully define the role of TFL in routine clinical practice.

Overall, the findings of this study support the growing body of evidence suggesting that TFL represents a meaningful technological advancement in ureteroscopic lithotripsy. Its superior operative efficiency, combined with comparable safety and a trend toward improved stone clearance, positions TFL as a compelling alternative to Ho:YAG laser for dusting-based fURS, particularly in patients with renal stones up to 20 mm.

CONCLUSION

In patients with renal stones measuring 10‑20 mm undergoing flexible ureteroscopy, Thulium Fiber Laser assisted dusting demonstrated superior operative efficiency compared with the conventional Ho:YAG laser, as evidenced by significantly shorter operative times. While stone-free rates were comparable between the two modalities, a consistent trend toward higher stone clearance was observed with TFL, without an associated increase in perioperative complications. These findings support the safety and clinical effectiveness of TFL and highlight its potential advantages in optimizing procedural performance. Larger multicenter randomized studies with longer follow-up are warranted to further validate these results and to establish the role of TFL as a preferred platform in contemporary endourological stone management.

TFL dusting during fURS demonstrated superior operative efficiency and comparable safety relative to Ho: YAG.

Author's Contribution:

Concept & Design or acquisition of analysis or interpretation of data:	Ali Mahmood Shakir, Banaz Salih Ahmed, Siba Mekaael Yaseen
Drafting or Revising Critically:	Hala Mahmood Mahdi, Ishraq Talib Hasan, Hasan Ali Alsailawi
Final Approval of version:	All the above authors
Agreement to accountable for all aspects of work:	All the above authors

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